PATENT SPECIFICATION 1,005,943

DRAWINGS ATTACHED.

Inventor:—MICHAEL THOMAS LEEDS.

1,005,943

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Int. Cl.:—H 05 k.

COMPLETE SPECIFICATION.

Multilayer Electrical Circuit Assemblies and Processes for Producing Such Assemblies.

We, INTELLUX, INC., a corporation organized under the laws of the State of California, United States of America, of 30 South Salsipuedes Street, Santa Barbara, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to printed circuits and, in particular, to multilayer circuits and to methods of making such circuits.

Printed circuits are ordinarily two-dimensional in nature and often utilize complex layouts to avoid cross-overs of the conductors. Some multilayer circuits have been developed and used but have various size, performance and economic disadvantages. It is an object of the present invention to provide a new multilayer circuit assembly and a process of making such a circuit which is compact, dependable and relatively inexpensive.

The present invention provides a multilayer circuit assembly, including first and second electrical circuits disposed in substantially parallel planes, an insulating layer positioned between said circuits, said layer having openings at zones where said circuits are to be electrically connected together, and a metal plug, formed by electrodeposition filling an opening in said insulating layer and interconnecting the adjoining portions of said first and second circuits providing substantially flat upper and lower surfaces over the entire zone of interconnection. The present invention also provides processes for producing such assemblies.

It is a feature that this circuit is not limited in the number of layers which can be utilized and will still provide firm electrical interconnection as desired between all layers. Circuit assemblies are currently being produced having twelve circuit layers with the over-all thickness of the layers being in the order of 0.070 inch.

It is also noted that the multilayer circuit has metallurgical bonds at the interconnections of the circuits. It is preferred to provide such an assembly in which the overlying circuits are produced by electrodeposition of metal to fix the circuits in place and produce the metallurgical bonding.

It is also important that this method insures that openings of various depths in the insulating layers between the circuits are completely filled with metal which is firmly bonded to each appropriate circuit. The metal interconnecting the circuits form plugs which are suitable for drilling for receiving wires and component leads with the metal plugs being homogeneous and anchored in place in the structure.

It is also of interest to note that the insulating layers in this multilayer circuit can have reinforcing sheets which also serve to anchor the intercircuit connections in place. The multilayer circuit may be prepared on an insulating base or on a conducting base and may be used in conjunction with additional circuit components. Also, the multilayer circuit may be made as an inlaid circuit having a flush surface suitable for switching and commutating applications.

The invention also comprises novel details of construction and novel process steps which will more fully appear in the course

of the following description. The drawings merely show and the description merely describes preferred embodiments of the present invention which are given by way of illustration or example.

In the drawings:

Figure 1 is a schematic diagram of a typical circuit to be produced by the invention;

Figures 2—7 illustrate steps in the preferred embodiment of the invention;

Figures 8—10 are diagrams of the individual circuits which are combined to produce the circuit of Figure 1;

Figures 11—14 illustrate steps in an alternative form of the invention; and

Figures 15 and 16 illustrate steps in another embodiment of the invention.

Figure 1 illustrates an electrical circuit which is to be produced by the process of the invention. The circuit includes a plurality of terminals indicated by dots 20, which terminals are interconnected in a particular pattern by conductors indicated by lines 21. It is required that there be no electrical interconnection between the conductors except at the terminals. Hence a circuit of the configuration of Figure 1 cannot be produced in a single layer. In the embodiment illustrated herein, the circuit of Figure 1 is produced in three layers which are separated by insulating coatings. Appropriate steps are performed to produce the required interconnections between the layers. The configuration of the first layer or first circuit is shown in Figure 8, the configuration of the second layer or circuit is shown in Figure 9, and the configuration of the third layer or circuit is shown in Figure 10. Overlying terminals are interconnected through the insulating coatings in a manner to be described below.

In the process illustrated in Figures 2—7, a first circuit 24 is applied to an insulating base 25. The base 25 may be a sheet of ceramic or plastic or may be a sheet of metal having an insulating coating on the surface thereof. The first circuit 24 may be applied by conventional methods, such as by an etched foil process or by painting or screening a conducting paste onto the base.

Next an insulating coating 26 is applied to the surface of the structure. The insulating coating is applied in a particular pattern, normally by a spraying or screening process, to cover at least those portions of the first circuit which are to be insulated from the second circuit and to leave exposed those portions of the first circuit which are to be electrically connected to the second circuit. Normally it is easiest to cover substantially the entire surface of the structure except for spots overlying the particular terminals which are to be interconnected with terminals of the second circuit. Typically, the insulating coating 26 will be an epoxy resin paint which is applied in a thickness in the order of 0.006 inch. The insulating coating 26 with an opening 27 therein is seen in Figure 3.

In the next step, a thin layer of electrically conducting material is applied over the entire surface of the structure. This thin layer is preferably in the order of one micron thick and may be applied by known processes, such as the chemical reduction process, or the vapor deposition process. The chemical reduction process is preferred as it provides a good metallurgical bond with the underlying metal. Ordinarily the thin layer 28 will be of copper but other metals may be used when desired.

After the insulating coating 26 has been applied and prior to application of the thin conducting layer 28, the exposed portions of the first circuit 24 may be built up to the level of the coating 26, by electroplating material in the openings 27. This provides a smooth surface for subsequent application of the thin layer 28.

In the next step, a second circuit 31 is applied on the thin conducting coating 28. Various processes may be used for applying the second circuit. In the embodiment of Figures 2—7, a mask 32 is applied over the coating 28 leaving exposed areas corresponding to the second circuit. The second circuit is then deposited by electroplating metal, ordinarily copper, onto the exposed areas of the thin conducting coating 28 to build up the second circuit to the desired thickness. It should be noted that the chemically deposited thin coating 28 will contact the first circuit 24 through the openings in the insulating coating 26 so that the electrodeposited second circuit fills these openings and is metallurgically bonded to the first circuit at the interconnection points. Ordinarily the masking layer 32 is then removed.

The exposed portions of the thin conducting coating 28 are now removed as by chemical etching. Since this coating is only about one micron thick, this etching process does not affect the second circuit which is in the order of three of four thousandths of an inch thick.

In an alternative process for applying the second circuit, a layer of metal may be electroplated onto the thin coating 28 to the desired thickness of the second circuit, usually about three thousandths of an inch. This electrodeposited layer is then masked in a configuration corresponding to the second circuit after which the exposed portions of the electrodeposited layer as well as the thin coating 28 thereunder are removed, as by chemical etching. Then the masking is removed.

Various conventional methods of applying the masking may be utilized, the well-

known photographic technique being preferred. In this process, a photosensitive coating is applied to the surface, the photosensitive coating is exposed to light in a predetermined pattern, and is then developed and fixed. The nonactivated portions of the photographic emulsion are washed away leaving a residue which constitutes the mask. The mask itself may be removed by using appropriate solvents. The details of this process are well known and will not be repeated herein.

The circuit assembly now has the configuration shown in Figure 5 and is complete for a two-layer circuit. The first and second circuits have been joined at the opening 27 in the insulating coating 26 by the metallurgical bond produced by electroplating which bonds through the thin coating 28 produced by chemical reduction. The metal plug in Figure 5 has a large diameter section 36, a small diameter section 37, and another large diameter section 38, the sections 36 and 38 corresponding to terminals 20 of the first and second circuits respectively. The insulating coating 26 extends into the groove provided by the section 37 resulting in a strong mechanical engagement between the various layers constituting the circuit assembly. In a typical unit, the terminal sections 36, 38 will have a diameter of 0.130 inch and the interconnecting section 37 will have a diameter of 0.090 inch. The plug may be drilled to receive a wire or component lead which ordinarily requires a 0.030 inch hole through the plug and the base.

The anchoring of the metal plugs may be materially improved by forming the insulating coating 26 in a plurality of layers. The insulating coating may be applied by screening a first layer of resin onto the surface, laying a porous sheet onto the screened layer, and screening a second layer of resin onto the porous sheet. The insulating coating is then set or cured in the usual manner. The two resin layers will be laid down in a predetermined pattern as discussed previously, to provide openings for interconnections between the first and second circuits. The porous sheet need not have any pattern formed therein as the chemical reduction process and the electroplating can take place through the porous material.

Typically, a six-thousandths inch thick insulating coating may be formed by screening on a one-thousandth inch layer of resin, laying on a four-thousandths inch thick glass cloth, and screening on another one-thousandth inch layer of resin. The glass cloth will preferably be in the order of 50 to 100 mesh and the electroplated interconnection between the circuits will be formed around the individual fibers of the woven cloth. This type of construction is of particular value where the metal plugs are used as terminals for components and wires which produce mechanical loads on the circuit assembly.

In another alternative, a perforated sheet, such as a sheet of "Mylar" (Registered Trade Mark) polyester resin having an all-over punching of relatively small openings or a pattern corresponding to the inter-circuit connections can be substituted for the cloth.

The resin layers used for insulating and adhesion may be applied by various methods. A layer may be applied in liquid form by silk screening or brushing. A layer may be formed as a dry, uncured sheet, then punched to the desired pattern and laid in place. In another alternative, the layer may be applied to the porous sheet and dried, prior to placing the porous sheet in position. Such resin layers may be applied to one side or both sides of the porous sheet as desired.

This multiple-layer insulating coating technique may also be used to incorporate an additional circuit layer into the assembly and is particularly useful in providing a terminal structure. For example, the porous sheet may carry one or more conductors which pass or terminate at the openings 27 and are joined to the underlying circuit by the subsequent electroplating operation.

Flexible harnesses are prepared by laminating a very thin sheet of copper to a sheet of glass cloth or "Teflon" or "Mylar" (Registered Trade Marks) film, followed by masking and etching to produce the desired circuit pattern.

In a typical multilayer circuit of the invention, such a flexible harness may be used as part of an insulating coating, with an end of the harness left exposed for external connections. A two-layer circuit can be formed using the first circuit 24 as one layer and a harness as the second layer, with interconnections made by electroplating plugs in the interconnection openings 27.

Additional circuits may be formed over the first and second circuits by repeating the process steps of Figures 3 and 4, as illustrated in Figures 6 and 7. Another insulating coating 41 is applied over the structure of Figure 5 with openings in the coating at points where the second and third circuits are to be interconnected. Then a thin conducting coating 42 is applied to the structure by chemical reduction and the third circuit 44 is applied in a predetermined pattern, established by a mask 43, after which the portions of the thin coating 42 not covered by the third circuit are removed. The completed three-layer circuit is shown in Figure 7. There is no limit on the number of layers of circuits which can be produced by this method. Extremely complex circuits with more than two thousand connections and

twelve layers of circuits are possible. The circuit assemblies may be produced in quantity and all will be identical since the routing of the conductors is controlled by the predetermined patterns and masks and conductors are not installed individually.

Another embodiment of the process of the invention is shown in Figures 11—14. This process is particularly suited for use in making circuits of the inlaid type having a flush surface for use with moving contacts in switching applications and the like. Referring to Figure 11, a first circuit 50 is applied to a temporary base 51 by any of the well-known methods. The temporary base 51 may be a sheet of metal, wood, plastic or the like. If formed of a nonconducting material, the base may have a metal film on the surface thereof. When the temporary base has an electrically conducting surface, the first circuit may be applied by electroplating, either through a mask or all over followed by etching to a desired configuration. An insulating coating 52 and a thin conducting coating 53 are applied in the manner described in conjunction with the embodiment of Figures 2—7. Then the second circuit may be applied and the remainder of the thin conducting coating removed, as described previously, to produce the structure of Figure 12.

A permanent base or support 54 is then laid over the upper surface of the circuit assembly and the entire structure is subjected to a suitable temperature and pressure to mold the permanent base to the circuit. The permanent base is preferably a sheet of uncured thermosetting plastic material and the molding pressure and temperature are chosen to produce setting of the plastic material and bond the base 54 to the circuit structure. The permanent base with the circuits inlaid therein may then be removed from the temporary base by thermal cr mechanical shock or peeling or stripping or chemically dissolving the temporary base. The resultant structure is shown in Figure 14 with the surface 56 having the conductors flush therewith and being extremely smooth.

Another embodiment of the invention is shown in Figures 15 and 16. In this embodiment, a first circuit conductor 70 and an insulating coating 71 may be applied to a base 72 in the manner previously described. If desired, the exposed surfaces of the first circuit 70 may be raised to substantially the level of the surface of the insulating coating 71 by electroplating metal onto the first circuit conductor to produce a metal plug 73 in the opening 74 of the insulating coating. This step was previously referred to in conjunction with Figure 3.

In the next step, a conducting material 76 is applied in a predetermined pattern over the surface of the structure. This conducting material defines the second circuit but only partially covers the exposed surfaces of the first circuit. Then the second circuit is applied by electroplating a layer of metal 77 onto the conducting material 76 and onto the remaining exposed portions of the first circuit 70. This operation produces a good metallurgical bond between the first and second circuit conductors regardless of the quality of the bond between the conducting material 76 and the first circuit.

The layer of conducting material 76 may be applied by various known processes. For example, the layer 76 may be applied by painting or screening a conducting paste onto the surface of the unit, followed by drying and, if desired, firing to produce the metallic conducting film. In an alternative mode, an appropriate mask may be applied to the surface of the insulating coating 71 after which the conducting material 76 is applied by chemical reduction or vapor deposition or the like. Then the mask is removed leaving the conducting material in the desired pattern. When applying the conducting material 76 over the exposed surface of the first circuit conductors, it is preferred to cover no more than about one third of the area of each opening exposing the first circuit conductor so that the maximum area is available for the electroplated metallurgical bond.

Although exemplary embodiments of the invention have been disclosed and discussed, it will be understood that other applications of the invention are possible and that the embodiments disclosed may be subjected to various changes, modifications and substitutions within the scope of the appended claims.

WHAT WE CLAIM IS:—

1. A multilayer circuit assembly, including first and second electrical circuits disposed in substantially parallel planes, an insulating layer positioned between said circuits, said layer having openings at zones where said circuits are to be electrically connected together, and a metal plug, formed by electrodeposition, filling an opening in said insulating layer and interconnecting the adjoining portions of said first and second circuits providing substantially flat upper and lower surfaces over the entire zone of interconnection.

2. An assembly according to claim 1, wherein said insulating layer comprises a first film of plastic, a porous sheet, and a second film of plastic, with each of said films having openings at zones where said circuits are to be electrically connected together.

3. An assembly according to claim 2, in which said porous sheet is a cloth woven of electrically nonconducting fiber.

4. An assembly according to claim 2, in which said porous sheet is a perforated plastic sheet.

5. An assembly according to any of claims 2 to 4, wherein the porous sheet is adapted for carrying the second electrical circuit or a third electrical circuit, with at least two of the circuits being electrically connected together by the metal plug.

6. A process of forming a multilayer electrical circuit, including the steps of: applying a first circuit of electrical conducting material in a predetermined pattern to a base; applying a coating of insulating material to said first circuit to cover at least those portions of said first circuit which are to be insulated from a second circuit and to leave exposed those portions of said first circuit which are to be electrically connected to the second circuit; applying a thin coating of conducting material over at least a portion of the exposed portions of said first circuit; electrodepositing a conducting material to build up said exposed portions to substantially the level of the surface of said coating of insulating material; applying a second layer of conducting material on top of the first thin conductive coating to form a second electrical circuit exhibiting a predetermined pattern; and, if necessary, removing the first thin conducting coating not covered by said second coating.

7. A process according to claim 6, including the steps of applying the thin coating of conducting material over all of the exposed portions of the first circuit, applying the second circuit of electrical conducting material in a predetermined pattern on said thin conducting coating; and then removing said first thin conducting coating not covered by said pattern of the second circuit.

8. A process according to claim 7, wherein the second electrical circuit is formed by masking the thin coating in a predetermined pattern leaving areas exposed defining the second circuit, electroplating metal onto the unmasked areas of said thin coating to form the second circuit; removing said masking; and removing the exposed portions of said thin coating.

9. A process according to claim 7, wherein the second electrical circuit is formed by electroplating metal onto the thin coating, masking said electroplated metal in a predetermined pattern covering areas defining the second circuit, and removing the exposed areas of said electroplated metal and the thin coating thereunder.

10. A process according to any of claims 6 to 9, wherein the thin metal coating is applied by chemically reducing a metal coating over the structure.

11. A process according to claim 10, wherein the insulating coating applied over the first circuit is continuous except for openings therein exposing portions of said first circuit which are to be electrically connected to portions of the second circuit.

12. A process according to any of claims 6 to 11, in which the first circuit of electrical conducting material is initially applied in a predetermined pattern to a temporary base, and wherein after the formation of the second circuit of electrical conducting material superposed on said first circuit, a layer of insulating material is applied against said second circuit and adjacent areas to provide a permanent base, and then said temporary base is removed from said circuits and permanent base leaving the second circuit inlaid in the permanent base.

13. A process according to any of claims 6 to 11, wherein a third electrical circuit is formed on said structure by applying a second coating of insulating material to said second circuit to cover at least those portions of said second circuit which are to be insulated from the third circuit and to leave exposed those portions of said second circuit which are to be electrically connected to the third circuit; applying a second thin coating of conducting material over the structure; applying a third circuit of electrical conducting material in a predetermined pattern on said second thin conducting coating; and removing the remainder of said second thin conducting coating.

14. A process according to any of the claims 6—13, in which the coating of insulating material applied to said first electrical circuit is formed by the steps of, applying a first layer of insulating material to said first circuit in a predetermined pattern having openings at areas where said first circuit is to be electrically connected to the second circuit, applying a layer of a porous solid insulating material to said first layer, and applying a second layer of insulating material to said porous solid layer in the pattern of said first layer.

15. A process according to claim 14, wherein said porous solid layer comprises a glass cloth.

16. A process according to claim 14, wherein the porous solid layer comprises a perforated plastic sheet.

17. A process of forming a multilayer electrical circuit, including the steps of: applying a first circuit of electrical conducting material in a predetermined pattern to a base; applying a first layer of fluid insulating material to said first circuit in a predetermined pattern having openings at areas where said first circuit is to be electrically connected to a second circuit, applying to said first fluid layer a layer of a porous solid insulating material carrying a second circuit of electrical conducting material; and electrodepositing metal onto said first circuit at said openings to substantially fill said open-

ings and interconnect said first and second circuits at predetermined points.

18. A process according to claim 17, wherein a third electrical circuit is applied to the superposed first and second circuits on said structure by initially applying a thin coating of conducting material over the structure, applying the third circuit of electrical conducting material in a predetermined pattern on said thin conducting coating, and removing the remainder of said thin conducting coating.

19. A process of forming a multilayer electrical circuit, including the steps of; applying a first circuit of electrical conducting material in a predetermined pattern to a base; applying a coating of insulating material to said first circuit to cover at least those portions of said first circuit which are to be insulated from a second circuit and to leave exposed connection portions of said first circuit which are to be electrically connected to the second circuit; electrodepositing metal onto said first circuit at said connection portions to substantially build up said exposed portions to the top level of the insulating material, applying a thin coating of conducting material in a predetermined pattern on the insulating material to define a second circuit, with said pattern partially covering said connection portions of said first circuit; and electroplating metal onto the conducting material and the uncovered part of said connection portions of said first circuit to form the second circuit.

20. A process according to claim 19, in which the conducting material defining the second circuit is applied by screening an electrically conductive paste onto the surface and drying the unit to produce a metallic film.

21. A process according to claim 19, in which the conducting material defining the second circuit is applied by masking the surface, applying a thin coating of conducting material over the masked surface, and removing the masking material.

22. A process of forming a multilayer electrical circuit substantially as herein described.

23. A multilayer circuit assembly constructed substantially as herein described with reference to the embodiments shown in the accompanying drawings.

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Chartered Patent Agents,
Agents for the Applicants.

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Published at The Patent Office, 25 Southampton Buildings, London, W.C.2,
from which copies may be obtained.

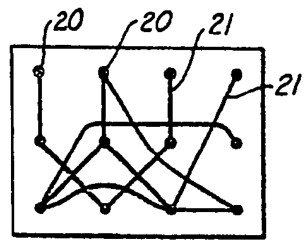


FIG. 1.

FIG. 2.

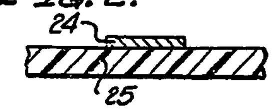


FIG. 3.

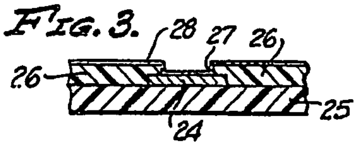


FIG. 4.

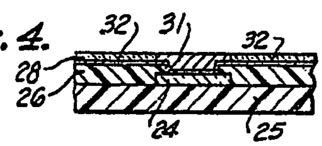


FIG. 5.

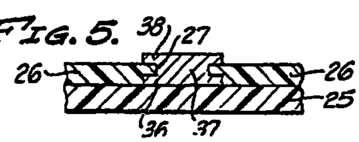


FIG. 6.

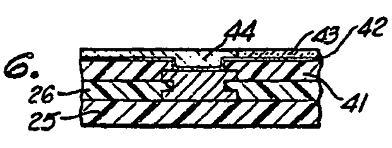
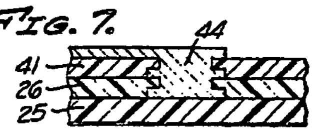


FIG. 7.



9. 1.

FIG. 8.

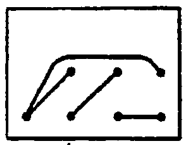


FIG. 9.

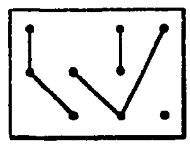


FIG. 10.

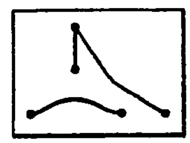


FIG. 11.

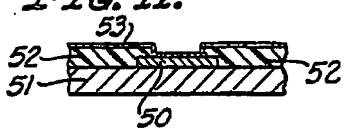


FIG. 12.

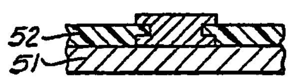


FIG. 15.

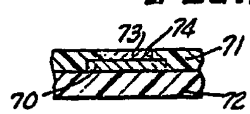


FIG. 13.

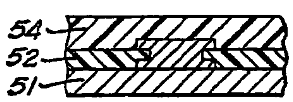


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FIG. 16.

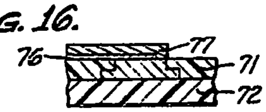
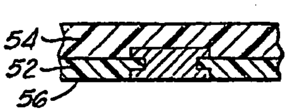


FIG. 14.



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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

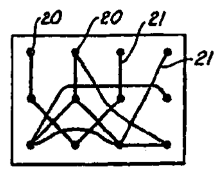

FIG. 1.

FIG. 2.

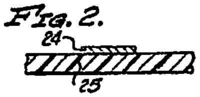

FIG. 3.

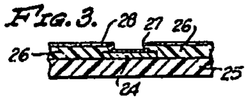

FIG. 4.

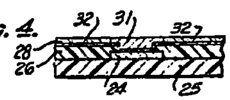

FIG. 5.

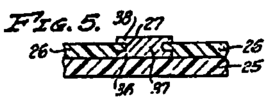

FIG. 6.

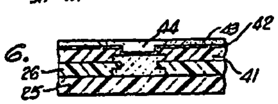

FIG. 7.

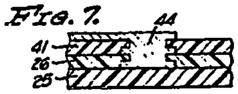

FIG. 8.

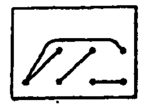

FIG. 9.

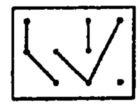

FIG. 10.

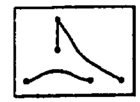

FIG. 11.

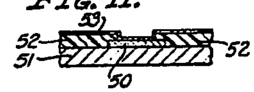

FIG. 12.

FIG. 13.

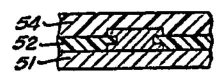

FIG. 14.

FIG. 15.

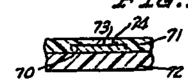

FIG. 16.